emy; Professer Ira Remsen, Baltimore, Md., foreign secretary; Mr. Arnold Hague, Washington, D. C., home secretary—each for a term of six years. The following were elected additional members of the council for the ensuing year: J. S. Billings, G. J. Brush, H. P. Bowditch, Arnold Hague, Simon Newcomb, L. P. Langley.

Five new members were elected as follows:

George F. Becker, U. S. Geological Survey, Washington, D. C.

J. McKeen Cattell, Professor of Psychology, Columbia University, New York City.

Eliakim H. Moore, Professor of Mathematics, University of Chicago, Chicago, Ill.

Edward L. Nichols, Professor of Physics, Cornell University, Ithaca, N. Y.

T. Mitchell Prudden, Professor of Pathology, College of Physicians and Surgeons, Columbia University.

The following were elected foreign associates:

J. Janssen, Director of the Observatoire d'Astronomie Physique, Meudon, France.

Mr. Loewy, Director of the Observatoire de Paris, Paris.

E. Bornet, of the Section of Botany of the Paris Academy of Sciences.

Hugo Kronecker, Professor of Physiology in the University of Bern.

A. Cornu, Professor of Physics, École polytechnique, Paris.

F. Kohlrausch, Professor of Physics at the University of Berlin.

Sir Archibald Geikie, recently Director of the Geological Survey of Great Britain.

J. H. van't Hoff, Professor of Chemistry in the University of Berlin.

The Henry Draper medal was awarded to Sir William Huggins, of London, for his investigations in astronomical physics.

THE SOCIAL SERVICE OF SCIENCE.*

The extent to which society may be considered as an organism is still, I understand, a matter of controversy with sociologists, but without awaiting its adjudication, we may surely make use of a simile as ancient as that of the Apostle who spoke of individual Christians as members of one body, or as that of the wise old Roman who taught the mutinous plebs the parable of the body politic, all of whose members were nourished by the well-fed patrician belly, and consider together this evening the special function of science in the body social.

It may at least supply a convenient means of classifying the various services of science to the common weal, if we consider it not as a distinct corporal member, but rather as a growth force, ever accelerating the evolution of society, providing it with organs of defense, increasing its muscular energy, and perfecting its systems of circulation and communication. And if to these services we add the reaction upon the social mind of the physical environment which science has provided, and the direct influence of scientific truth, we shall then have sketched at least the main functions of science in social evolution.

Among the first services to society which our biologic analogues suggest is that of defense. Under the growth force of science the body social has accomplished an evolution similar to that which brought the vertebrates, assumed to have been at first naked and defenseless, to the stage of the armored fishes of the Devonian, and which in the Tertiary changed tooth to tusk, nail to claw, and frontal boss to horn and antler.

Prescientific society was destroyed largely because it had attained no adequate means of defense. It is safe to say that had the Roman legionaries been equipped with Maxims and Mausers, the episode of the Hun and Vandal invasions of Southern Europe would have been indefinitely postponed.

Modern society, which science has armed with the most terrible of death-dealing weapons, whose explosives are brought from the laboratory of the chemist, whose im-

*Address of the retiring President, Iowa Academy of Science. Des Moines, December 26, 1900.

mense guns are fired at ranges which require the rotation of the earth to be taken into account, and with a precision which considers the difference in density of the air at the top and at the bottom of the bore, whose war ships are armored with the latest discoveries of metallurgy, their turrets turned and their guns loaded and trained by the electric current, and their evolutions directed by invisible vibrations of ether—surely a society thus armed has nothing to fear from any barbarian peril, be it yellow or be it black.

Civilization is safeguarded by science not only from the irruption of savage hordes, but also from the invasion of disease, from such epidemics as that which in the middle of the 14th century swept away more than half the population of England, and twenty-five millions of people in Europe. To-day when the plague appears in San Francisco or in London, it excites little more alarm than Gibraltar would feel at the assault of the Moor. By the simple remedy of vaccination science has saved in each generation of the century more lives, it is said, than were lost in all the wars of Napoleon. Among civilized nations within the last five centuries the death rate has been so lowered that the average duration of human life has nearly doubled. Medicine no longer attacks disease with charm, exorcism and nostrum; she obtains her weapons from the armory of science. From chemistry she brings a pure materia medica, new compounds, new processes, new methods of diagnosis, and anesthetics which have made surgery painless. From physics she obtains the appliances of electro-therapeutics, a delicate cautery, and the Röntgen ray, used by physicians in almost every town of size in Iowa within less than half a decade of its discovery.

The debt of the healing art to the sciences of the biologic group is so vast that I will select but one, bacteriology, for illustration. It is to no lucky chance that the discovery is due of man's most subtle and deadly foes, the bacteria. The work of Pasteur, the pioneer, and of his illustrious followers, is marked by the most thorough and painstaking investigation, and the most searching and rigid tests. It is by the application of the scientific method that the enemy has been unmasked, his ambuscades and chosen places for assault discovered and rational methods for his destruction demonstrated. It is men of science who have organized the victory of medicine to-day over diphtheria, rabies and the plague, over the venom of the snake and all the diseases to which serum therapathy is successfully applied. And where the bacteriologist cannot as yet supply a specific for disease, he can often point the way to its prevention. When the access to the human system of the germs of typhoid and cholera by drinking water is demonstrated, Hamburg builds its filter beds at a cost of $2,280,000 and Chicago expends $33,000,000 upon the drainage canal. And so with the great white plague, tubercular consumption. Science has proved the lurking places of the contagium in the sputum, and its carriage in the air we breathe, and reinforced by the high moral sense of our people, she is fast making it as impossible for the consumptive to spit on the pavement unhindered as for the smallpox patient to walk unarrested down our streets.

And who can estimate the number of lives now saved in each generation by aseptic surgery? So long as putrefaction was held, as by Liebig, to be due to the action of the oxygen of the air, no remedy for it could be suggested; but when once its bacterial origin was proved, the step was inevitable to those precautions which have rendered safe and successful the marvelous operations of modern surgery.

Micro-biology extends her ægis also over

the herds and crops of man. She destroys the insect enemies of our grain fields and protects vine and fruit tree from blight and mildew. She saves the silk-worms of Europe from the plague threatening their destruction, and the flocks and herds of America from some of their most destructive diseases.

Thus science performs a service to society incalculable in its value. It defends it from foes both within and without the gates. It prolongs life, assuages pain, lessens disease and makes death a euthanasy. So notable have been its victories during the century that we may almost prophesy the coming of the time when the only deadly bacillus remaining will be that as yet undescribed species, *bacillus senectutis*, or at least when only sufficient disease will be left on earth to provide for a speedy and beneficent extirpation of the unfit.

Viewing organic evolution from the angle of the physicist and considering the animal body simply as a machine for the transformation of potential into kinetic energy, the secular process sums itself up in the production of better and better machines. From the fish of the early Paleozoic, on to the amphibians of the Carboniferous, the reptiles of the Mesozoic, and the mammals of the Tertiary and of the present, we have a series of higher and higher organisms, each capable of doing more work and better work than its predecessors.

It is possible to construe social evolution in the same terms. Primitive society was weak. The energy at its disposal was that only of the human body, the beast of burden, and, to a limited extent, of wind, water and flame. So feeble was the ancient state in what may be termed its musculature, so little could it utilize the forces of nature, that it may be compared with a stage of organic evolution preceding that of the vertebrata, that, let us say, of the turbellarian worm, 'whose arrangement of muscles,' biologists tell us, 'is far from economical or effective.'*

In comparison modern society may be likened to one of the higher mammalia, such as the tiger or the elephant, which can not only take up from nature the maximum of energy, but can also apply it in varied movements and a highly complicated conduct.

Consider the vast stores of energy which society has to-day at its disposal. The steam power of the United States alone equals the day labor of one hundred million men. Behind each man, woman and child of the nation stands more than one automaton of steel, with the strength of a man but with manifold his capacity for productive labor. In carding, for example, fingers of steel do in half an hour what the unaided workman of a century ago could not have accomplished in less than eight months. Society finds in machinery a tireless hand capable of performing the mightiest and the most delicate of tasks with equal ease. It strikes with the steam hammer a blow of 2,000 tons, and it rules the Rowland grating with its 48,000 parallel lines to the inch.

Consider also the new induement of energy which science has bestowed upon society in the gift of electricity, a power capable of the swiftest and most ready transmission, of infinite subdivision, and of the greatest known intensity of concentration. And how varied is its functioning. In mine and quarry it picks and drills and fires the blast. At the wharf it lifts and loads and carries. In the factory it forges, casts, welds and rivets. In the home it shines in the most healthful light yet made by man. In electrolysis it produces a hundred substances of value, such as the caustic alkalies, bleaching powder, chloroform, the chlorates, and aluminium, the metal perhaps to give name to the new

* J. M. Taylor, 'Whence and Whither of Man,' Morse Lectures, 1895, N. Y., 1896, p. 47.

century. From the refuse of the mine it extracts millions of dollars worth of the precious metals. It surfaces the common metals with those more beautiful and precious, and copies infallibly the engraved plate of the map and the type-set page. In the electric furnace it creates new compounds, calcium carbide the source of acetylene gas, carborundum the abrasive of the future, and calcium nitrate, which promises a new source of nitrogen to fertilize and renew exhausted soils everywhere. It aids in the synthesis by which the chemist builds out of the inorganic the dye, the perfume, the essence, and soon perhaps the food, which nature builds only by the processes of life. Such are some of the functions of the new muscular system with which electrical science has equipped the body social.

It is not claimed that pure science is the only factor in industrial progress. Invention, business sagacity, and many other causes cooperate. But the work of science is essential, fundamental, creative. How far unaided invention can go may be seen in China. Here is a people once pliant of intellect and inventive. As artificers they still are given high praise. But Chinese invention, destitute of all scientific foundation, stopped with the fire cracker, the movable type and the directive loadstone. It could not possibly go on to the Lyddite shell, the Hoe printing press, and the compass of Lord Kelvin. Invention is applied science, and as has been well said, science must first exist before it can be applied. Between the scientific investigator, the discoverer of principles, and the inventor who applies them, there need be no jealousy. If the last has the popular fame and the financial reward of the present, it is often to the first that the future belongs, and, in any event, in the words of the generous Schley at Santiago 'There is glory enough for all.' And after all why should the name of science be refused to that vast body of knowledge, classified and tested, which is in daily use in the laboratories of the industries of the world.

But to science even in its most restricted sense the debt of society is incalculable. It has evoked those good genii, steam and electricity. Watt was led to the invention of the steam engine, not by a boy's glance at his mother's tea kettle, but through the discovery by Black of latent heat and after two years of profound study of such abstruse problems as the specific volume of steam and its law of tension under varying temperatures. And the improvements in the steam engine, which since the fifties have more than doubled the speed of the piston, while saving at least one-fourth of the fuel, have been made under the guidance of Joule and the mechanical theory of heat. In the matter of the advantage of superheated steam and high pressure, theory still seems to outrun practice.

In electricity the mechanic can take no important step beyond the scientific discoverer. How happy was the thought which designates the various units of electricity by the illustrious names of the masters of research: volt, in honor of the professor in the University of Pavia, who, one hundred years ago, gave the world in his crown of cups its first effective reservoir of the new power; ampère, the name of the professor of physics in the College of France, founder of the science of electro-dynamics; ohm, in memory of the professor of experimental physics in the University of Munich, discoverer of the law of the strength of the electric current; and farad, in honor of the greatest of them all, Michael Faraday, professor of chemistry in the Institution of England, the prince of experimenters, whose researches, resulting in the dynamo, connected the industries of the world with the first economical source of electrical energy.

Illustrations of the dependence of industry on pure science are everywhere at hand. When, as an amateur in photography, I take up a package of eikonogen or hydroquinon, the label with the name of one of the great aniline factories of Germany, at Elberfield, Mannheim or Berlin, reminds me of the debt of the *Farbenfabriken* to men of research. To the chemist is not only due the discovery of my developers, and of such other by-products as antipyrine, cocaine, saccharine and vanilline; it was he who first found in the black amorphous coal tar, the former refuse of the gas works, those brilliant crystalline dyes which have so largely replaced other colors in the dye vats of the world. So far as I am aware, no monument has been raised to these discoverers, to Hoffman, Graebe and Liebermann. In a more telling way industry acknowledges her debt to pure science when a great aniline factory such as that at Elberfield employs sixty professional chemists, and turns the attention of twenty-six of them to pure research in discovery of new compounds.

Science has thus given society command of energies of the highest efficiency. It has made the comforts of life common and cheap, it has lifted from the shoulders of labor its heaviest burdens and set free for higher social services all who are capable of their performance. It is the undiminishing fountain whence flows the world's material wealth.

The evolution of the circulatory system in the body physiologic suggests a similar development in the body social. The process which during the geologic ages slowly changed the primitive gastro-vascular cavity to the perfected circulation of the higher animals to-day, which evolved from a simple pulsating tube the powerful four-chambered heart, may at least serve as a simile to the evolution of the distributory or transportative system of modern society. So obvious is the analogy that the arteries of commerce is a phrase of common parlance. But for our purpose it will not be necessary to carry the likeness into details, to discriminate, as some ingenious sociologists have done, the various organs, such as the capillaries of the body social, or to liken the red corpuscles of the blood to the golden discs of the circulating medium. Let it suffice to show that by the application of the discoveries of science society has obtained a system incomparably rapid and effective for the distribution of power, of food and of all the products of labor.

The world is enmeshed by lines of railway and steamship. They carry the products of our Iowa farms to western Europe, to South Africa and to China. To our dinner tables they bring in return linen from Ireland, porcelain from France, cutlery from old England and silverware from New England, meats and fruits from States as distant as Texas, California and Florida, spices from the East Indies, and beverages from Japan and Java and the valley of the Amazon. In the United States alone there are now in operation nearly 200,000 miles of railway carrying each year a billion tons of freight and five hundred and fifty millions of passengers.

The carriage of power is accomplished at present almost wholly by the transportation of fuel. The value of this service may be seen by contrast with some railroadless country such as China, where, according to Colquhon, coal selling at the mine at fifteen cents per ton costs as many dollars ten miles away. But the future doubtless has in store the distribution of power as an article of merchandise. The possibility of long-distance transmission of electricity has already been demonstrated at Niagara, and the time may be near when in our cities power from coalfield or waterfall may be purchased for use in factory and home as readily as water or gas to-day.

What has been said already of the debt of industry to science in the development of its motive powers applies here equally in transportation. Permit a single illustration further of the value of pure science in the evolution of the circulatory system. Every engineer is aware of the large contribution which the steel rail has made to the success of the railway. Durable, strong and cheap, it has displaced on all our railways the weak and short-lived rail of iron. It has made possible heavier trains and higher speeds. Together with other factors it has so cheapened traction that, according to Professor J. J. Stevenson, the coal of West Virginia is now sold at New York City for less than one-fourth the railway freight charges of a quarter of a century ago. But it is no belittlement of the laurels of Sir Henry Bessemer, the inventor who has made all this possible, to point to the fact that the success of his process, which, by ushering out the Age of Iron, and ushering in the Age of Steel, has revolutionized industry and touched every home with its beneficence, is due not only to his use of a great body of facts in the chemistry of the metals, but in especial to the utilization by Mushet of the facts regarding the influence of manganese and its relation to carbon, facts ascertained in the laboratories of science and left on record to await their use by invention at the proper time.

The mobility in the social organism so largely due to science has had far-reaching effects. It stimulates production to the utmost. It opens the markets of the world to the products of every worker. Labor has itself become mobile, and in the factory raw material from distant lands meets operatives from across the seas. It is the cause of vast migrations, such as that which has brought to the United States more than nineteen and a quarter million people since the opening of steamship routes across the Atlantic. It makes impossible in civilized lands such famines as that which in 1878 in two of the northern provinces of China destroyed more than nine millions of men. It opens to the occupation of a single homogeneous civilized commonwealth such vast areas as the Mississippi valley. To any such it would be as fatal to stop the social circulation made possible by science, as in a limb of the body to ligate the main artery. Dense populations can indeed exist wherever food can be raised in abundance, as on the river plains of China, but without the modes of distribution introduced by the science of the nineteenth century, they neither can be unified into a homogeneous community nor can they be lifted to the levels of modern civilization.

By its systems of circulation which break down all barriers, science has brought about the supreme crisis in social and political evolution. Like the epeirogenic movements which mark the crises in geologic history, which united continents and precipitated alien upon indigenous fauna, science has brought civilization and barbarism the world over in all their stages to meet in a life and death struggle, and offers to the fittest the prize of a world-encircling empire.

The fact that in order to operate the railway it is necessary to send signals at greater speeds than those of moving trains, suggests another service of science—the highest material service which it renders the common weal. In the telegraph and telephone a system is supplied for the almost instantaneous transmission of motor and sensory impulses throughout the body politic. In general terms we may compare the growth of the communicating system of society to the development of the nervous system in the history of animal life, where the scattered central cells of nature's first sketch of such a system are later gathered into ganglia, and ganglia massed into a brain connected with every part of the body by ramifying nerve filaments. Of all social

organs this seems the most retarded in its evolution. In primitive society it is only the smallest groups, such as the family and the village community, which have a facility of communication comparable with that of the lowest of the metazoa. In the larger groups of the tribe and nation we find a stage more advanced than that of the hydra only after science has made possible the railway post and the telegraph and telephone.

That Morse is the inventor of the electric telegraph is a statement more veracious than that of the Vermont farmer who said that everybody knew that Edison invented electricity. But the name of the inventor of every tool of society is legion. Morse set the keystone of the arch, but its voussoirs had been built by investigators unknown to popular fame in many lands, and even the keystone was almost placed in the hands of the distinguished inventor by Henry, the great physicist. And Oersted, who in 1819 deflected the magnetic compass by a voltaic current in a neighboring wire; Arago, whose experiments with iron filings proved that this current would generate magnetism; Ampère with his suggestion of the possibility of signaling at a distance by the deflection of needles; Sweiger, who took up Oersted's experiment, and discovered that the deflecting force of the current was increased when the wire was coiled about the magnet; Sturgeon, who, making use of Arago's discovery, replaced Sweiger's magnetic needle with soft iron and thus constructed the first temporary or soft magnet; Henry, who strengthened the electro-magnet and used it with over a mile of wire to give signals by tapping a bell—all of these men, devoted solely to knowledge for knowledge's sake, are sharers with Morse and Vail in the glory of the invention of the telegraph.

And so with wireless telegraphy. In Marconi's hand this invention blazes with a sudden brilliance which attracts the attention of the world, but the torch has been conveyed to him along the line of many runners in the torch race of scientific discovery. From Clerk Maxwell, who showed the analogy between electricity and light; from Hertz, with his demonstration of electromagnetic waves; from Onesti of Fermo, and Branly of Paris, and Lodge of London, whose researches produced in the coherer an instrument capable of seeing such waves; from these and others the torch was passed on to the great inventor whose improvements in apparatus made effective the discoveries of science.

In the telephone at least four scientific principles are involved—the voltaic current, the interaction of magnetism and electricity, the temporary magnet and the microphonic action of carbon. Through this marvelous invention each master in electrical science from the time of Galvani who has aided in the elucidation of these principles, though dead, yet speaketh.

Thus we may fairly claim that to science is due in large measure the plexus of post, telegraph and telephone, by which intelligence is flashed throughout the body social even more swiftly than along the nerves of the body physiologic. And how incalulable is the service which science thus renders! Consider the extent of the channels of communication. The domestic mail service of the United States requires each year twenty-one million miles of travel. Sixty-four years ago the first commercial telegraph was built with a length of forty miles. At the close of the century there are not less than one million miles of telegraph in the United States, over which duplex and multiplex messages are carried at the same time, and the rate of transmission has risen to six thousand signals per minute. One hundred and seventy thousand miles of submarine cables moor coasts, islands and continents together. Over one million

miles of telephone wires have already been strung in our own country. Boston, a typical city, measures its electric nerves at a total of one hundred and seventy million feet, and the radius of audible speech from it reached a year since, according to Iles, to Duluth, Omaha, Kansas City, Little Rock and Montgomery.

Note the saving of time and energy thus accomplished. Without leaving his desk the manager of a business is in instant communication with all his employees, and with the business enterprises in his own and other cities. The captains of industry are thus able to command armies of a size unthought of a few decades since. So accurate and instant are the new motor and sensory nerves that the oil refineries, the copper mines, the steel mills, almost any industry that may be mentioned, can be regimented under one control, and an industrial revolution is accomplishing before our eyes.

The electric wire with the fast mail and the newspaper flash the news of the world throughout all civilized countries. When our army attacks Santiago or marches on Pekin, the public becomes impatient of even the interval between the morning and the afternoon paper. On the night of a national election the American public listens to the count of votes in every city and in every State. The new discovery of science, the new mechanical process, the new remedy for disease, are communicated without delay to the entire world. In commerce local prices seek the level of the world market, and the entire distributing system is as effectively controlled as are the capillaries of the animal body by the clutches of the nerves. In a theater vast as the whole earth we look down on the stage upon which is played the never-ending drama of current history.

In a still larger sphere the new organ of communication has a reflex on civilization. It makes possible self-governing communities stretching from the Atlantic to the Pacific and even the federation of the world. Bringing Washington face to face with London, Paris and Berlin, and the other capitals of Europe, it enables the great powers of two continents to arrange without delay a concert of action whose message flashes round the planet and is carried into effect at Tien Tsin and Pekin. In direct contrast unscientific China outspreads her bulk like some vast insensate vegetal growth. Under attack, even at a vital point, she can neither mobilize her armies nor even disseminate a knowledge of the danger before it is too late.

It has been said by Giddings that objectively viewed progress is an increasing intercourse, a multiplication of relationships, an advance in material well-being, a growth of population, and an evolution of rational conduct. Subjectively it is the expansion of the consciousness of kind.*

In all these respects science has been an accelerating force in the evolution of society. Increasing food supply by means of scientific agriculture, lengthening life by the repression of diseases, and introducing a thousand new means of livelihood, it has made possible the extraordinary recent growth of civilized nations. It permits the population of Europe to more than double since 1800, and enables England, which in the seventeenth century men thought too small for its scanty population, to support more than 38,000,000 people in comparative comfort. It lends some encouragement to the sanguine prophecy of Albert Bushnell Hart that the Mississippi valley will sooner or later contain a population of 350,000,000.†

At the same time science has produced a heterogeneity of structure. The scientific principle discovered to-day flowers to-morrow in invention and produces the seeds of

* 'Principles of Sociology,' New York, 1896, p. 359.

† 'The Future of the Mississippi Valley,' Harper's Mag., Vol. 100, p. 419.

special arts and crafts. To Volta's researches in his villa on Lake Como five million men now employed in the many various arts connected with electricity owe in a measure their livelihood. In promoting the development of the complex organs of society for the handling of energy, for distribution, and for communication, science has constantly been a differentiating force.

By the same means it is accomplishing a more and more complete integration. The separate life of primitive society, the old personal independence, is gone. In the new order all social units and aggregations are interdependent. We are all members of one body. We must not ignore the purely psychic factors of social progress, but these alone could not maintain the new order apart from the physical basis built by science, itself a psychic factor. Were this support withdrawn, it would seem that over large areas now occupied by civilization, society must lapse and break into fragments fast degenerating into the state of the villages of the Russian plain, the scattered communities of the southern Appalachians or even to the pueblos of Arizona.

As we have spoken of the service of science in promoting the physical well-being of society, there remain of Professor Giddings's notes of social progress only the evolution of rational conduct and the consciousness of kind. These phenomena are involved in the evolution of the social mind. Here science acts directly and also by the reflex of the social organism. The organic unity of society is the ground for the expansion of the consciousness of kind. The social ties woven by science help to produce a wider social sympathy. Under the régime of science the barriers of the mark break down everywhere to make way for the market, and with their downfall the provincialism, indifference and hate of once separated peoples pass away. Science has created, as we have seen, a new physical environment which reacts constantly on the social mind, awakening from torpor, stimulating to greater activity, demanding a more alert attention, and a precision and swiftness of movement before unknown.

Still more directly is science creating an intellectual milieu whose influence on the social mind is as inescapable as is that of climate on the physical life. The world of our forefathers, how close its confines, how dark and shadowy, how uncertain and untrue, compared with the illimitable sphere which science now fills with her clear light. It is a universe, not a multiverse, the new world which science apperceives. It is a world of law, in which each event has adequate cause; the expression of one immanent energy operating across all widths of space and throughout all lengths of time, without loss or increment, and without variableness or shadow of turning; an eternal becoming an evolving order which comprehends the growth and decay alike of solar systems and of the humblest of living creatures. It is of this new world that the two master Victorian poets, inspired by both the scientific and the religious spirit, have written:

> All's law, but all's love.

and,

> One God, one law, one element,
> And one far off divine event
> To which the whole creation moves.

The effect of these new cosmic conceptions of science penetrates every department of learning and every field of life. It revolutionizes society. It rationalizes the social mind. It has swept to the limbo of things that are not the sprites of evil which affrighted our forefathers. In this science has done a work which neither literature nor art nor religion nor ethical culture has proved itself able to accomplish. It was the pious Melancthon, the gentle scholar of the Reformation, who at Heidelburg saw in falling stars only the paths of

deceitful devils, and the mandarin to-day, learned in all the ethical wisdom of Confucius, a classical scholar of the finest literary taste, still burns his firecrackers at the funeral of a friend that he may frighten away the pestiferous spirits of evil which dog the steps of men through life even to the threshold of the world beyond.

The rationalizing influence of science upon civilization needs no illustration to one versed in the literatures of the prescientific ages, to one who has read Plato's 'Timæus' or Plutarch's description of the moon. And how preposterous were the theories current but a century since, such as those which saw in fossils the freak of some plastic power in nature or the remains of a catastrophe which swept away in a flood of waters the very foundations of the earth. To-day how rare and how interesting are such survivals of this almost forgotten time as the Atlantis of Ignatius Donnelly!

The theory of evolution furnishes one of the best examples of the replacement of the untruths of the past by truths discovered by science, and of their revolutionary effect. Since the discovery of the proofs of this process, man has come to know himself as never before. He understands at last the meaning of history and rewrites his texts on philology, literature and all social and political institutions. He sees, though as yet dimly, some solution to the ethical problems of sin and evil, and beholds as in a panorama the process of his creation.

It is as yet too soon to see the full effect of these new conceptions upon the social mind. Science has not yet come to its own in education, and the irrational and the unreal are far from being wholly banished from society. But more and more the care of the young is entrusted to science to train, as none other can, to be quick of eye, true of speech, and rational in thought, to bring them face to face with reality and to open to their view the widest and most inspiring vistas. Common knowledge is one of the strongest social bonds. We meet and touch in what we know. The time has been when educated men drew together in a common knowledge of phrases written in extinct languages. To-day they find this rapprochement, this consciousness of kind, more and more in a common training in science. In the laboratory they have measured the energy of the falling body and studied its transformation into sound, heat, light, chemism and electricity; they have tested the ray from the hydrogen atom and found its vibration the same from the flame on the table and in the light of Sirius. They have dissected the tissues of life, and have read in Nature's book the life histories of mountain, river and planet. And thus to-day they have attained to that cosmic conception, overwhelming in its sublimity, which is the best gift of science to man.

The reward which science asks for this service is the wages of going on; she asks for well-equipped laboratories, for longer courses of scientific study in schools, for the endowment of scientific instruction and research. Such foundations as the Lawrence Scientific School, the Field Columbian Museum, and the Smithsonian Institution are examples of appreciation as yet as rare as munificent. I am not aware of any such in Iowa. When wealth builds the spacious laboratory or endows a chair in science in any college of the commonwealth, it is but rendering to science her own. Each dollar earned by railway, telegraph and telephone, mine and quarry, mill and factory, farm and store, may well pay tithe to science which has made these industries possible. The gratitude for a life saved by the applications of science in modern medicine might well be generous. And yet the total gifts to scientific instruction in Iowa by men of wealth do not exceed $50,000. I am aware of the State appropriations to the

scientific departments in our State institutions, and I should be glad to call them generous. At least they have given Iowa the fame of men whose work in science has achieved national recognition. But these yearly appropriations, were they many times as great, could not supply the place of the great gifts, endowments to be for all time reservoirs of power transmuted constantly into the highest social service. It is the boast of American democracy that by such votive offerings it shows appreciation of education, charity and scientific research.

As members of a guild of workers in science, let us be thankful for even the humblest place. To discover any fact, however trivial, to add anything, however slight, to the sum of human knowledge, this is to shape and dress some stone for the building of science, the home and shelter of the race. Our contribution may go to chink some crevice, or at least some master builder may find in it the keystone of an arch or the cap stone of a column. But whatever its place, if our work was well and truly done it abides as a permanent service to society.

WILLIAM HARMON NORTON.
CORNELL COLLEGE, MT. VERNON, IA.

A NEW CONNECTION BETWEEN THE GRAVITY MEASURES OF EUROPE AND OF THE UNITED STATES.

ABSOLUTE measures of gravity, repeated by different observers using different instruments at identical stations, have shown comparatively large disagreements. The general experience has been that differential measures of gravity are much more accurate than absolute measures, and there has, therefore, been a growing tendency to use the differential method rather than the absolute method. The results of such differential measures may be reduced to absolute units either by connecting by the relative measures many stations at which absolute measures have been made and then making an adjustment to get a mean value, or a single determination of the absolute value of gravity, which is believed to be of a much higher degree of accuracy than any other, may be used in reduction to absolute units.

These general conditions, especially with respect to gravity stations in Europe and the United States, led naturally to the campaign of differential gravity measures carried out by Assistant G. R. Putnam, of the Coast and Geodetic Survey, in the summer of 1900, under the direction of the International Geodetic Association.

The compact and portable half-second differential pendulums known as A4, A5 and A6, and of the type developed under the direction of Dr. T. C. Mendenhall while he was superintendent of the Coast and Geodetic Survey, were swung at Washington in May and again in October, 1900. Between these dates they were also swung at the Kew University, Greenwich Observatory, London Polytechnic Institute, Paris Observatory and at Potsdam, Germany, and thus served to determine with considerable accuracy the relative values of gravity at these points. Some of the principal previous determinations of gravity which have been made at or near these stations, and are therefore connected by the observations of 1900, are at Washington, by Preston in 1889–90, and Defforges in 1893; at the Kew Observatory, by Heaviside in 1873–74, by Herschel in 1881–82, by Walker in 1888, by Von Sterneck in 1893; at Greenwich Observatory, by Von Sterneck in 1893; at the London Polytechnic Institute, by Sabine, Kater and Herschel; at the Paris Observatory, by Defforges in 1892, and Von Sterneck in 1893. At Potsdam the observations connect with a most elaborate and painstaking determination of the absolute value of gravity which is now in